Award: 99HQGR0077

EARTHQUAKE SIMULATIONS AND GROUND MOTION PREDICTION FOR THE SAN FRANCISCO BAY REGION

Ralph J. Archuleta
Kim B. Olsen

Institute for Crustal Studies
University of California, Santa Barbara 93106

Phone: 805-893-8441 (RJA)
Phone: 805-893-7394 (KBO)
FAX: 805-893-8649
Email: ralph@crustal.ucsb.edu
Email: kbolsen@crustal.ucsb.edu

Technical Abstract

We have simulated three **M** 7.0 earthquakes on the Hayward fault. Each simulation assumes a kinematic model of the faulting process on a specified fault plane. The fault is embedded in a one-dimensional velocity structure. The computations are done using a 3D finite difference code. These simulations are the initial step in preparation for 3D simulations using a realistic, inhomogeneous velocity structure and more complicated kinematic source models. The three scenarios involve two unilaterally propagating ruptures—one southeast to northwest and the other northwest to southeast—and one bilateral rupture. Two horizontal (parallel to strike and perpendicular to strike) and the vertical components of ground motion are computed. Within five kilometers of the strike, all three components of particle velocity are near or exceed 100 cm/s. Rupture directivity plays a key role in amplifying the peak velocity. As expected directivity has a significant affect as the rupture propagates along strike, but it also has a significant affect when the rupture propagates from the hypocenter toward the earth's surface. For distances 10 kilometers or more from the fault, the Love wave creates the largest amplitudes off the fault.

We have determined the kinematic faulting parameters of the 1989 Loma Prieta earthquake using thee-dimensional Green's functions to account for the material heterogeneity in the region. Using the USGS velocity and attenuation structure (Brocher et al., 1997) we have computed 3D Green's functions.with a viscoelastic finite difference code (Liu and Archuleta, 1999). We inverted 48 time histories of particle velocity (three components at 16 stations) that were derived from the acceleration recordings of the mainshock. From the inversion we determine the spatial and temporal behavior of five kinematic parameters that characterize the kinematics of faulting: slip amplitude, slip rake, rise time, rupture velocity and the temporal behavior of the slip rate function. We use a nonlinear algorithm (Liu et al.,1995a,b) that combines simulated annealing and simplex methods to search for the parameters that produce the best fit between synthetic time histories and the data. We find a bimodal slip distribution that is dominated by strike-slip motion southeast of the hypocenter (maximum of ~4.5 m) with a concentration of dip-slip northwest of the hypocenter (maximum 3 m). These areas of large slip are approximately 13-15 km either side of the hypocenter with little slip directly updip from the hypocenter. Total seismic moment is 3.8×10^{19} N-m. The rupture velocity is nearly constant with an average value near 2.5 km/s. The slip is maximum southeast of the hypocenter, but the slip rate is maximum (~4-5 m/s) northwest of the hypocenter, implying a larger stress drop to the northwest.

Award: 99HQGR0077

EARTHQUAKE SIMULATIONS AND GROUND MOTION PREDICTION FOR THE SAN FRANCISCO BAY REGION

Ralph J. Archuleta
Kim B. Olsen

Institute for Crustal Studies
University of California, Santa Barbara 93106

Phone: 805-893-8441 (RJA)
Phone: 805-893-7394 (KBO)
FAX: 805-893-8649
Email: ralph@crustal.ucsb.edu
Email: kbolsen@crustal.ucsb.edu

NON-TECHNICAL ABSTRACT

We have used two approaches to understand the ground motion in the San Francisco Bay area. In the first approach we compute the ground motion that is representative of a magnitude 7 earthquake on the Hayward fault. As expected the areas within 2-3 miles of the fault trace experience the largest ground motion. The amplitude of the ground motion depends on where the earthquake starts. The maximum ground motion is not near the beginning of the earthquake, but rather in the areas closest to where the earthquake rupture stops. However, because of the properties of the earth, an earthquake on the Hayward fault can also generate significant ground motion up to 20 miles away because of a wave guide effect. These waves, technically called Love waves, will cause a sideways motion of the ground that could be damaging to some structures.

In the second approach we have re-investigated the 1989 Loma Prieta magnitude 6.9 earthquake. In previous research investigators approximated the Earth in the region as a vertical stack of layers that had different material properties. However, the USGS has recently determined an Earth model that varies both horizontally and with depth. We have used this more realistic Earth model to account for the wave propagation of the seismic waves in our determination of the faulting. We have used a sophisticated numerical method that searches for a set of parameters distributed on the fault such that there is agreement between computed ground motion and observed ground motion. We find a faulting model that has a bimodal distribution of slip on the fault plane. The rupture radially spreads out from the initiation with a speed that is about 1.8 miles/s (Mach 6). Slip over the entire fault is complete after about 10 seconds. We have found that the more realistic Earth model provides better agreement between computed and observed motions compared to earlier attempts to model the ground motion.